REWARD

REal World Advanced Technologies foR Diesel Engines

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Project partners:

1 - AVL - AVL List GmbH - AT
2 - REN - Renault SAS - FR
3 - VCC - Volvo Car Corporation - SE
4 - CRF - CRF SCpA - IT
5 - CNRIM - Instituto Motori – Consiglio Nazionale delle Ricerche (CNR) - IT
6 - JM - Johnson Matthey Plc - UK
7 - RIC - Ricardo Plc - UK
8 - SCF - Schaeffler AG - DE
9 - LMM - Le Moteur Moderne - FR
10 - DELPHI - Delphi Automotive Systems Luxembourg S.A. - LU
11 - UNR - Uniresearch BV - NL
12 - IFPEN - IFP Energies Nouvelles - FR
13 - VIF - Virtual Vehicle Research Center - AT
14 - CTH - Chalmers Tekniska Högskola - SE
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Publishable Executive summary

Recognising that real-world NO_X emissions have not decreased at the same rate as the legislated light-duty diesel (LDD) passenger car tailpipe emissions (from Euro 1 to Euro 6) the European Union is introducing the Real Driving Emissions (RDE) legislation with the aim to ensure real world and urban NO_X emissions reduction. As part of Work Package 2 within the REWARD project exhaust thermal management strategies have been evaluated with the aim to improve the aftertreatment efficiencies. This report details the multi-cylinder steady-state engine testing activities within task 2.2. The main activity of this task was to evaluate exhaust thermal management (ETM) technologies and strategies, and the effect on the aftertreatment system.

Following simulation both exhaust variable valve timing and early exhaust valve opening systems were taken forward to the multi-cylinder engine testing phase for a full evaluation of the optimum approach to exhaust thermal management. Traditional in-cylinder strategies such as multiple fuel injections, combustion retard and charge mass reduction were also considered, separately and in combination. For initial temperature gain at the keypoints tested the current approach to exhaust thermal management (without exhaust valve modulation) was seen as preferable – there was no fuel consumption benefit from advancing the exhaust valve timing or increasing the valve curtain area. Whereas, for maximum temperature gain within engine stability and smoke emissions limitations, exhaust valve phasing or exhaust valve opening advance when twinned with in-cylinder approaches is preferable compared to the baseline engine build approach to exhaust heating. The higher in-cylinder residuals from variable exhaust valve timing were shown to aid temperature uplift at low loads and speeds as the residual gas is hotter than external EGR when targeting the same NO_X emissions. At higher load and speed the additional in-cylinder residuals and the subsequent effect on volumetric efficiency impacts the extent of combustion retard and mass flow reduction that can be achieved for temperature uplift.

Drive cycle simulation has shown the benefit of exhaust thermal management for improving cycle NO_X emissions with a subsequent fuel consumption penalty. Variable exhaust valve timing was seen to improve the cycle NO_X:CO_2 trade-off for a DOC+aSCRF system when high levels of NO_X reduction are required compared to an in-cylinder approach for exhaust heating. Over the WLTC there is a 1.4% improvement in CO_2 when targeting a 22% reduction in cycle NO_X. Simulation of an LNT+aSCRF aftertreatment system has shown limited sensitivity to the exhaust thermal management approach.

For the DOC+aSCRF aftertreatment system an exhaust variable valve timing system was shown to result in the lowest CO_2 penalty compared to other exhaust thermal management approaches with a relatively low system oncost. It was seen within the testing and simulation tasks that the early exhaust valve opening system was not as effective as variable exhaust valve timing and that the electrically heated catalyst approach is hampered by electrical system losses. Owing to the reduced urban environment NO_X slip risk compared to the DOC system event with variable exhaust valve timing, and the CO_2 benefit from reduced exhaust thermal management requirement the recommendation for the WP2 application is LNT+aSCRF with in-cylinder ETM.